Ontario Geological Survey
Aggregate Resources Inventory Paper 63

AGGREGATE RESOURCES INVENTORY OF THE TOWNSHIP OF EAST ZORRA-TAVISTOCK

Oxford County

SOUTHERN ONTARIO

by
Staff of the Engineering and Terrain Geology Section
Ontario Geological Survey

1983

Ontario
Ministry of Natural Resources
Hon. Alan W. Pope
Minister
W. T. Foster
Deputy Minister

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ISSN 0708-2061
ISBN 0-7743-6010-0

This report was prepared by: Staff of the Aggregate Assessment Office, Engineering and Terrain Geology Section of the Ontario Geological Survey, Ontario Ministry of Natural Resources, 77 Grenville Street, Toronto, M5S 1B3. Telephone (416) 965-1182.

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The Mineral Resources Staff of Aylmer District and Southwestern Region of the Ministry of Natural Resources assisted in the collection of data, field checking and review of this report.

Parts of this publication may be quoted if credit is given to the Ontario Ministry of Natural Resources, Ontario Geological Survey. It is recommended that reference to this report be made in the following form:

Ontario Geological Survey
1983: Aggregate Resources Inventory of the Township of East Zorra-Tavistock, Oxford County; Ontario Geological Survey, Aggregate Resources Inventory Paper 63, 33 p., 7 tables, 3 maps, scale 1:50 000.

Every possible effort is made to ensure the accuracy of the information contained in this report, but the Ministry of Natural Resources does not assume any liability for errors that may occur. Source references are included in the report and users may wish to verify critical information.

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ABSTRACT

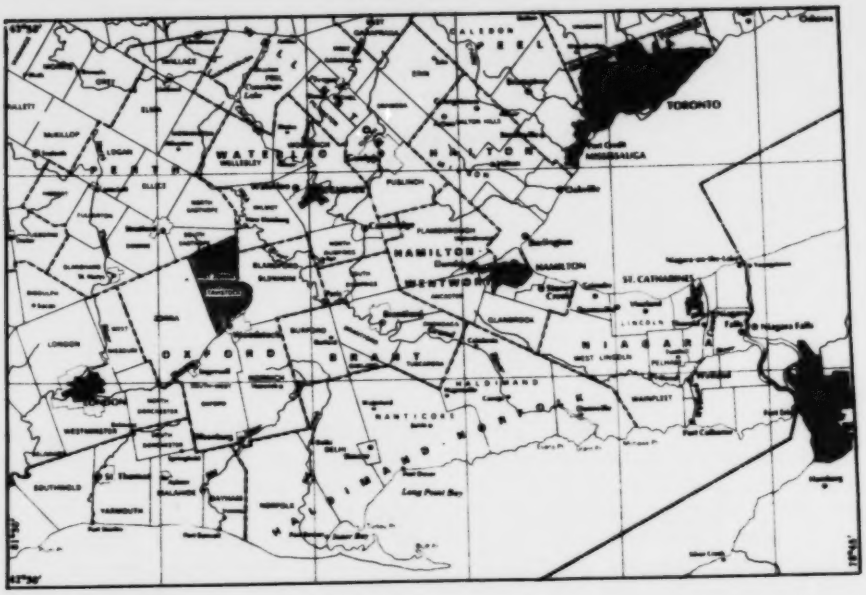

Figure I - Key Map Showing the Location of the Township of East Zorra-Tavistock, Scale 1:1 800 000.

This report includes both an inventory and evaluation of sand and gravel as well as bedrock resources in the Township of East Zorra-Tavistock. The report is part of the Aggregate Resources Inventory Program for townships and municipalities designated under The Pits and Quarries Control Act, 1971.

In the Township of East Zorra-Tavistock, three areas containing sand and gravel have been selected for possible resource protection. The Selected Sand and Gravel Resource Areas of Primary Significance have a total of 600 acres (243 ha), exclusive of licenced properties. An estimated 410 acres (166 ha) are currently available for extraction, containing possible resources of 18 million tons (16 million tonnes). The available portions of the Selected Areas represent six percent of the total area occupied by sand and gravel deposits in the township and seven percent of the total resource tonnage.

Selected Sand and Gravel Resource Areas 1a and 1b are outwash deposits located east of Braemar. The available portions of Areas 1a and 1b are 55 acres (22 ha) and 155 acres (63 ha), with possible sand and gravel resources of 2 million tons (2 million tonnes) and 6 million tons (5 million tonnes), respectively.

Selected Resource Areas 2a and 2b are ice-contact stratified drift deposits located north of Woodstock. Areas 2a and 2b have possible sand and gravel resources of 2 million tons (2 million tonnes) and 6 million tons (5 million tonnes), respectively.

Selected Resource Area 3 is composed of two small outwash deposits located in the centre of the township. Resource Area 3 has sand and gravel resources of approximately 2 million tons (2 million tonnes).

Data from the Ontario Ministry of Transportation and Communications indicate there is a chert content of 10 to 20 percent in the granular deposits in the township. Therefore beneficiation is recommended to improve the quality and potential use of the aggregate. Generally the material in the primary selected areas is suitable for Granular Base Course A, B, C; 5/8 inch (16 mm) crushed gravel and select subgrade aggregate. With blending and sand control the material from most of the selected areas may be used for some hot-laid sand products (Deike 1981).

Three outwash deposits, two ice-contact stratified drift deposits and an alluvium deposit have been suggested as Resource Areas of Secondary Significance.

The Township of East Zorra-Tavistock has low to moderate possible resources of sand and gravel. Therefore care should be taken to ensure the continuing availability of as much of the remaining resources as possible.

Bedrock underlying the township consists of dolomitic shale and dolostone of the Salina and Bass Islands Formations, cherty limestone of the Bois Blanc Formation, and limestone and dolostone of the Amherstburg and Lucas Formations of the Detroit River Group. Most of the township is covered with drift exceeding 100 feet (30 m) in thickness. No bedrock areas have been selected for possible resource protection because of the thickness and quality of the bedrock, and the thickness of overlying drift.

Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

AGGREGATE RESOURCES INVENTORY OF THE TOWNSHIP OF EAST ZORRA-TAVISTOCK[1]

BY
STAFF OF THE ENGINEERING
AND TERRAIN GEOLOGY SECTION

INTRODUCTION

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1979, the total tonnage of mineral aggregates extracted was 144 million tons (131 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1980).

Although mineral aggregate deposits are plentiful in southern Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterised by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand, gravel and crushed bedrock. The most recent information available has been used to prepare the reports. As new information becomes available, revisions may be necessary.

[1] Manuscript accepted for publication by Chief Engineering and Terrain Geology Section, April 30, 1982.
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PART I - INVENTORY METHODS

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References). Wherever possible, field examination of potential resource areas was also undertaken to confirm interpretations made in the office. Field methods included the examination of natural and man-made exposures of granular material. Most observations were made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites included estimates of the total face height and the proportion of gravel- and sand-size fragments in the deposit. Observations were also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, test pitting, soil probing and hand-augering techniques were used to assess subsurface materials. Air photos at various scales were used to determine the continuity of deposits, especially in areas of limited subsurface information.

In the office, the pit data were supplemented by information on file with the Engineering Materials Office of the Ontario Ministry of Transportation and Communications. Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size, and depth of extraction of pits licenced under The Pits and Quarries Control Act, 1971 were obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above named groups in the compilation of inventory data is gratefully acknowledged.

Water well records, held by the Ontario Ministry of the Environment, were used in some areas to corroborate thickness estimates, or to indicate the presence of buried granular material. These records were used only in conjunction with other evidence. Topographic maps of the National Topographic System, at a scale of 1:50 000, were used as a compilation base for the field and office data. The information was then transferred to a township base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been drawn, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows: First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot thick layer of sand and gravel, one acre in extent, assuming an average density of 110 pounds per cubic foot.

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 represent only those parts of the deposit lying outside licenced areas (Column 2).

Two successive subtractions are made from the unlicenced area. Column 3 accounts for the number of acres unavailable due to the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas lying outside of licenced properties that have previously been extracted (e.g. wayside pits are included in this cateogry). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage presently available for extractive development and/or resource protection.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of favourable bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated workable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of a workable thickness of 60 feet (18 m) is used. Volume estimates are then multiplied by 3600 (the estimated weight in tons of a one-foot thick section of dolostone, one acre in extent, assuming a bulk density of 165 pounds per cubic foot).

Resources of sandstone are calculated using a bulk density estimate of 146 pounds per cubic foot or approximately 3200 tons per acre. Shale resources are calculated on the basis of a bulk density estimate of 150 pounds per cubic foot.

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompny the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel as well as bedrock-derived aggregates are termed possible resources in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p. 7) and with the Association of Professional Engineers of Ontario (1976) (see Glossary, Appendix B).

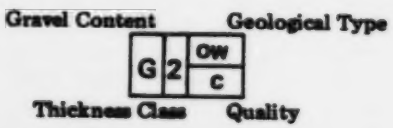
PART II - DATA PRESENTATION AND INTERPRETATION

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources", shows the distribution of bedrock formations, the distribution of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Map 1 is derived directly from the existing surficial geology maps of the area or from air photo interpretation where surficial mapping is incomplete. It shows the extent of sand and gravel deposits within the study area and serves as a base for the calculation of the total sand and gravel resources.

Map 1 presents a summary of all available information related to the quantity and quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbol which identifies each deposit. The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for a given deposit. These components are illustrated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess fines may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate makes up less than 35 percent of the whole deposit. "G" indicates that the aggregate probably contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identify the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identify the main quality limitations that may be present in the deposit as discussed in the next section.

The other information presented on Map 1 is designed to give an indication of the present level of extractive activity in the study area. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating under authority of a permit) are also identified and numbered on Map 1 and described in Table 2.

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary; secondary; and tertiary. These areas are identified on Map 2 by different shading patterns.

Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by a medium-grey tone on Map 2.

Selected Aggregate Resource Areas of primary significance are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such resource areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by a light grey tone on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resource areas in a municipality, they may contain large quantities of sand and gravel and should be considered an integral component of the aggregate supply of the municipality.

Areas of tertiary significance are indicated on the map by a dashed line but have no grey tone. They are neither rated nor considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extraction development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the municipality is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

DEPOSIT SIZE

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1, i.e. those thicker than 20 feet (6m) and containing more than 35 percent crushable gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

AGGREGATE QUALITY

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the symbol for each deposit on Map 1. They are: gravel content (G or S); fines (C); oversize (O); and lithology (L).

Three of the indicators deal with grain size distribution. The "gravel content", (G or S), indicates the suitability of aggregate for various uses. Deposits containing more than 35 percent crushable gravel are considered to be favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Exesss "fines" or high silt and clay content may severely limit the potential use of an aggregate. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fine content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent "oversize" particles (those greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building

aggregate, so must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

The other indicator of the quality of an aggregate is "lithology". Just as the unique physical and chemical properties of bedrock formations determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high-quality uses. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol indicates either "C" "O" or "L" or any combination, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt has been made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of the Ontario Ministry of Transportation and Communications and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations. The Engineering Materials Office of the Ontario Ministry of Transportation and Communications has recently compiled a detailed assessment of aggregate suitability for selected areas in southern Ontario. This material has been consulted extensively in preparation of the inventory reports.

LOCATION AND SETTING

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of those natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3.

The assessment of sand and gravel deposits and bedrock resource areas with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report but readers are encouraged to discuss them with personnel of the Ontario Ministry of Natural Resources' District Office.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain at roughly the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalities with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological

data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, bedrock topography, drift thickness maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources), and from geotechnical well data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the labelled bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of the areas of thin drift are shown by three tones. The darkest tone indicates areas where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas constitute potential resource areas of primary significance due to their easy access. The medium tone indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these also represent potential resource areas. The lightest tone indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive sand and gravel deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the municipality. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner, location, and licenced acreage of the quarry and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating under authority of a permit) are also identified and numbered on Map 3 and described in Table 5. One additional symbol appears on the map: an open dot indicates the location of a selected well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot.

SELECTION CRITERIA

Criteria equivalent to those for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation and Communications. The main characteristics and use of the bedrock formations found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations of sufficient thickness to support quarry operations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource is usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of bedrock resource areas has been restricted to a single level of significance. Three factors support this approach. Quality and quantity variations are gradual. The areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material. Since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The wider range of possible resource areas allows greater flexibility in locating quarry operations away from areas of intensive land use competition. The Selected Areas are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such a resource area may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

PART III - ASSESSMENT OF AGGREGATE RESOURCES IN THE TOWNSHIP OF EAST ZORRA-TAVISTOCK

LOCATION AND POPULATION

The Township of East Zorra-Tavistock occupies an area of 60,544 acres (24 502 ha) in north-central Oxford County and is shown on portions of the Stratford (40 P/7) and Woodstock (40 P/2) map sheets of the National Topographic System at a scale of 1:50 000. The township is bounded on the north and northeast by South Easthope Township and the Township of Wilmot; on the east by the Township of Blandford-Blenheim; on the south by the townships of Norwich and South-West Oxford and on the west by the Township of Zorra.

The largest centre in the township is Tavistock, located on the northern boundary. The City of Woodstock and the Town of Ingersoll are the major trade and retail centres, although they are located outside of the township to the south and southwest, respectively. Smaller settlements within the township include Hickson, Innerkip, Strathallan, and Braemar.

The population of the township in 1980 was 7108 and statistics indicate the population has increased by 23 percent since 1972 (Ontario Ministry of Intergovernmental Affairs 1981; Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1974). The majority of the population is rural-farm, although there is an increasing number of rural non-farm residents.

Road access in the township is provided by King's Highways 59 and 2 and a grid of paved county roads and gravel-surfaced township roads. The township is serviced by the Canadian National Railways, which passess through Tavistock in the north, and the Canadian Pacific Railway which traverses the south and passes through Innerkip.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The physiography and distribution of surface material in the Township of East Zorra-Tavistock is the result of glacial activity that took place in the Late Wisconsinan Substage of the Pleistocene Epoch. This period of time which lasted from approximately 23 000 to 10 000 years ago was marked by the repeated advance and melting of massive, continental ice sheets.

The Township of East Zorra-Tavistock was subjected to two lobes of glacial ice, one originating in the Lake Ontario-Lake Erie basins, and the other in the Lake Huron basin. The township is predominantly covered by the Tavistock Till and has topographic features characteristic of a drumlinized till plain. It is part of the physiographic area described by Chapman and Putnam (1966, p. 231) as the Oxford Till Plain. Drumlins of the Woodstock drumlin field and glacial flutings occur in the southern and northern part of the township, respectively. Cowan (1975) suggests the drumlins were formed initially by the Erie lobe and were then modified by the Huron lobe which advanced from the northwest and deposited the Tavistock Till. Both the drumlins and the glacial flutings formed in the Tavistock Till are oriented in a southeast-northwest direction. Glaciolacustrine sand and silt deposited at a later time tend to modify the original relief of the till plain.

The most distinctive features in the township are the glacial meltwater channels, created during the recession of the margin of the Huron lobe. They are now occupied by the underfit streams of the Thames River and Mud Creek. Sand and gravel outwash deposits occur as terraces along these meltwater channels and as fill along small channels which lie between Mud Creek and the Thames River. Where channels were not deeply incised, meltwaters were able to spread over low-lying areas and deposit the various materials (Cowan 1975). Cowan (1975) describes the outwash material as varying from coarse cobble or boulder gravel with 20 percent sand, to fine pebble gravel and gravelly sand where sorting is highly variable. Small scattered outwash sand and gravel deposits in the township indicate local deposition by proglacial or subglacial meltwaters (Cowan 1975).

The ice-contact stratified drift deposits located east and west of King's Highway 59 in the southern part of the township are described by Hewitt and Karrow (1963). These deposits represent kame gravels overridden by till associated with the Woodstock drumlin field. The

large ice-contact stratified drift deposits north of Braemar are described by Cowan (1975) as representing deposition in a re-entrant phase of the retreating Huron ice lobe. Scattered ice-contact stratified drift deposits mapped by Karrow (1971) in the northern portion of the township are the result of deposition during the retreat of the margin of the Huron ice lobe. Cowan (1975) suggested that sand and gravel may be derived from reworked till or gravel in alluvial deposits.

Chert, a deleterious material in concrete and asphalt, is found throughout the sand and gravel deposits in the township. The chert was derived mainly from the underlying bedrock of the Bois Blanc Formation (Deike 1981).

EXTRACTIVE ACTIVITY

At least nine sand and gravel pits have been opened in the Township of East Zorra-Tavistock in the past. Many of these properties have become inactive since the designation of the township in 1975 under The Pits and Quarries Control Act, 1971. At the time of writing only two sources were licenced for extraction. The total area licenced for sand and gravel extraction is 155.0 acres (62.7 ha).

Since the designation of the township, records of the total annual production from all licenced pits have been maintained by the Aylmer District Office of the Ministry of Natural Resources. The average annual production from 1976 to 1980 has been 177,712 tons (161 220 tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREAS

Sand and gravel outwash and ice-contact stratified drift deposits selected for possible resource protection at the primary level in the township occupy a total of 600 acres (243 ha), exclusive of licenced areas. Cultural constraints reduce the presently available area to 410 acres (166 ha). Using an average deposit thickness estimate for each resource area, the total sand and gravel resources are approximately 18 million tons (16 million tonnes). The primary resource areas represent six percent of the total area occupied by sand and gravel deposits in the township and contain seven percent of the total resource tonnage. The Ontario Ministry of Transportation and Communications (M.T.C.) indicates that chert, a deleterious material, is found throughout the deposits in the township. The chert was derived mainly from the underlying Bois Blanc Formation, and makes up approximately 10 to 20 percent of the sand and gravel deposits. However, beneficiation procedures may be used to remove the chert and improve the quality and potential uses of the aggregate.

SELECTED SAND AND GRAVEL RESOURCE AREAS 1a AND 1b

Selected Sand and Gravel Resource Areas 1a and 1b are outwash deposits located east of Braemar. The Areas are terrace deposits laid down by Huron lobe meltwaters which flowed along the Mud Creek channel. One pit (pit no. 1), presently licenced for extraction, is located in Selected Resource Area 1a. Faces in the pit, 15 to 18 feet (5 to 6 m) in height, expose fine to coarse sand showing cross-bedding and cut and fill structures with well rounded, moderately sorted gravel occurring in pockets and seams. The aggregate may be suitable for Granular Base Course (G.B.C.) A, B and C, 5/8 inch (16 mm) crushed A and B, select subgrade aggregate and various hot-laid stone and sand products. Beneficiation and blending may be required (Deike 1981).

Area 1a occupies a total of 70 acres (28 ha), exclusive of licenced areas. Cultural constraints reduce the area available for extraction to 55 acres (22 ha). Assuming an average thickness of 15 feet (5 m), the sand and gravel resources are approximately 2 million tons (2 million tonnes).

Assuming similarity in origin with Area 1a, Selected Resource Area 1b may contain similar material. There are no pits in this deposit, although subsurface drilling (Test hole nos. EZ-TH-1 and 2) revealed fine to coarse sand with some fine gravel. The material may be suitable for a variety of road construction aggregate products (Deike 1981).

Area 1b occupies a total of 190 acres (77 ha). Cultural constraints reduce the area available for extraction to 155 acres (63 ha). Based on an estimated deposit thickness of 15 feet (5 m), approximately 6 million tons (5 million tonnes) are available for extraction.

SELECTED SAND AND GRAVEL RESOURCE AREAS 2a AND 2b

Selected Sand and Gravel Resource Areas 2a and 2b are located north of Woodstock and consist of ice-contact kame sands and gravels overlain by till (Hewitt and Karrow 1963).

Presently there is one licenced pit (pit no. 2) in Selected Resource Area 2a. At the time of field investigation, extractive activity was located on the lowest of three levels. An exposed face, 20 to 25 feet (6 to 8 m) in height, revealed sub-rounded to rounded pebbles and cobbles interspersed with silt and fine to coarse sand. On average the deposit contains 40 to 45 percent gravel. The material may be suitable for G.B.C. A, B and C, 5/8 inch (16 mm) crushed A and B, select subgrade aggregate and some hot-laid stone and sand products, however sand control for G.B.C. A and beneficiation could be required (Deike 1981). Area 2a occupies a total of 55 acres (22 ha), exclusive of licenced areas. Cultural constraints reduce the area available for extraction to 35 acres (14 ha). Using an estimated deposit thickness of 25 feet (8 m), the available resource tonnage is approximately 2 million tons (2 million tonnes).

One pit (pit no. 3), located in Selected Resource Area 2b is described by Cowan (1975, p. 64): "A 25-foot (8 m) northeast face consists of cross-bedded sands and gravels, the material is coarser towards the top of the face and grades downward into fine to medium sands at the base. A few thin layers of well sorted pebble gravel occur .... Pebbles and cobbles are rounded to well rounded in this pit." The material may be suitable for G.B.C. A, B and C, 5/8 inch (16 mm) crushed B, select subgrade aggregate and hot-laid sand products although blending and beneficiation could be required (Deike 1981).

Area 2b occupies 190 acres (77 ha), exclusive of licenced areas. Cultural setbacks reduce the available area to 90 acres (36 ha). Assuming an estimated deposit thickness of 25 feet (8 m), sand and gravel resources are approximately 6 million tons (5 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 3

Selected Sand and Gravel Resource Area 3 is composed of two small outwash gravel deposits located in the centre of the township. Three pits (pit nos. 5, 6 and 7) are located in the Area. Faces in the pits are 6 to 10 feet (2 to 3 m) in height and expose horizontally bedded, moderately sorted sand and gravel. Oversize material is present. The material may be suitable for G.B.C. A, B and C, 5/8 inch (16 mm) crushed A and B, select subgrade aggregate and some hot-laid stone and sand products, with blending and beneficiation being required (Deike 1981).

Area 3 occupies 90 acres (36 ha); cultural setbacks reduce the available area to 74 acres (30 ha). Using an estimated deposit thickness of 10 feet (3 m), the resource tonnage is approximately 2 million tons (2 million tonnes).

SAND AND GRAVEL RESOURCE AREAS OF SECONDARY SIGNIFICANCE

Three outwash and two ice-contact stratified drift deposits and an alluvium deposit have been suggested as Resource Areas of Secondary Significance.

The outwash gravel deposits are located in the southern part of the township. One deposit is located approximately 4 kilometres southwest of Innerkip. The material is described by M.T.C. as cobbly gravel with fine pebbly medium to coarse sand. The material may be suitable for various road-building aggregate products (Deike 1981).

The two remaining outwash gravel deposits lie north and west of the City of Woodstock. Cowan (1975) identified both areas as containing granular material, although further investigation is required to delineate the extent of the resources.

Two ice-contact stratified drift sand deposits selected at the secondary level are located west of Hickson. Pit no. 8, located in the northern deposit, has a 10- to 20-foot (3 to 6 m) face, consisting of fine to coarse sand, with some oversize material. The material may be suitable for G.B.C. B and C, select subgrade aggregate and some hot-laid sand products (Deike 1981).

The alluvial sand deposit, south of Braemar, has been selected since it was identified by Cowan (1975) as containing possible sand and gravel resources. More information is required to delineate the extent of this resource area.

BEDROCK GEOLOGY

Bedrock underlying the Township of East Zorra-Tavistock consists of dolomitic shale and dolostone of the Upper Silurian Salina and Bass Islands Formations, cherty limestone of the Lower Devonian Bois Blanc Formation, and dolostone and limestone of the Middle Devonian Amherstburg and Lucas Formations of the Detroit River Group (Cowan 1975; Sanford 1969). The formations have a gentle dip toward the southwest. Generally the thickness of surficial material overlying bedrock is greater than 100 feet (30 m). However, along the Thames River, near Innerkip and the City of Woodstock, the drift is less than 50 feet (15 m) thick and at the former Innerkip quarry the Bass Islands and Bois Blanc Formations are exposed.

The oldest formation in the township, the Salina, consists of non-fossiliferous grey to greenish-grey shales and shaly dolomites containing gypsum lenses (Cowan 1975, p. 6). The formation is mined to the northwest, in Goderich, for salt and to the east, in Drumbo, for gypsum. Drift thickness over the Salina exceeds 100 feet (30 m), thus the formation has not been considered for possible resource protection.

The Salina Formation is conformably overlain by brown to buff, dense fine-grained dolomite of the Bass Islands Formation which in turn is disconformably overlain by medium-crystalline, highly fossiliferous cherty limestones of the Bois Blanc Formation (Cowan 1975). The Bass Islands Formation was quarried in the past at Innerkip for lime and crushed stone for railway ballast, but this quarry has been out of use for some time and is presently rehabilitated (Cowan 1975). The material from both the Bass Islands and Bois Blanc Formations may be suitable for G.B.C. A and sub-base aggregate. In addition, sections of Bass Islands Formation may be suitable for hot-mix paving and structural concrete uses (Deike 1981). The Bois Blanc Formation is not suitable for these uses because of the high chert content. Although quarries might be established in the area of thin drift around Innerkip, the area has not been selected for protection because of the quality of the bedrock and the availability of aggregate from other sources.

The Amherstburg and Lucas Formations of the Detroit River Group overlie the Bois Blanc Formation. The Lucas Formation consists of very high purity calcium limestone while the Amherstburg Formation contains a significant amount of chert. Farther west in the Beachville-Ingersoll area, the high-calcium Lucas Formation is extensively extracted since it is the thickest, most uniform and purest high calcium limestone in Ontario (Hewitt and Vos 1972). The limestone is used for the manufacture of lime, fluxstone, portland cement and minor crushed stone in this area (Hewitt 1972). In the Township of East Zorra-Tavistock, however, the Lucas Formation has only a limited thickness and is covered by more than 50 feet (15 m) of drift through most of its occurrence in the township. For these reasons, quarrying is not considered economic. As a result, no areas of the Lucas Formation have been selected for resource protection.

SUMMARY

The Township of East Zorra-Tavistock has low to moderate possible sand and gravel resources which should be sufficient for local use in the near future. Several outwash and ice-contact drift deposits and an alluvium deposit have been selected for possible resource protection and care should be taken to ensure the availability of these resource areas.

Possible bedrock resources in the township are limited by the thickness and quality of the rock, as well as the thickness of overlying drift. As a result most of the township's aggregate requirements must be supplied by the sand and gravel deposits.

Enquiries regarding the Aggregate Resources Inventory of the Township of East Zorra-Tavistock should be directed to the Ontario Ministry of Natural Resources either at the Aylmer District Office, 353 Talbot Street West, Aylmer, Ontario N5H 2S8 (Tel. (519) 773-9241) or at the Southwestern Region Geological Office, 458 Central Avenue, London, Ontario N6B 2E5 (Tel. (519) 433-8431).

TABLE 1 | TOTAL SAND AND GRAVEL RESOURCES, TOWNSHIP OF EAST ZORRA-TAVISTOCK

1 CLASS NO.	2 DEPOSIT TYPE (see Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)
1	G-IC	325 (132)	16 (14)
	S-IC	720 (290)	36 (33)
	G-OW	175 (71)	11 (10)
	S-OW	1250 (510)	62 (56)
2	G-AL	170 (69)	6 (5)
	S-AL	40 (16)	2 (2)
	S-IC	100 (40)	4 (4)
	G-OW	295 (119)	13 (12)
	S-OW	2190 (890)	82 (74)
3	S-AL	40 (16)	1 (1)
	G-IC	70 (28)	1 (1)
	S-IC	30 (12)	1 (1)
	S-LP	740 (300)	15 (14)
	G-OW	255 (103)	3 (3)
	S-OW	305 (123)	6 (5)

TABLE 1 | TOTAL SAND AND GRAVEL RESOURCES, TOWNSHIP OF EAST ZORRA-TAVISTOCK

1 CLASS NO.	2 DEPOSIT TYPE (see Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)
4	G-IC	4 (2)	<1 (<1)
	S-IC	65 (26)	1 (1)
	S-LP	205 (83)	2 (2)
	S-OW	150 (61)	2 (2)
		7100 (2850)	265 (240)

N.B. Minor variations in above table are due to rounding of data.

TABLE 2 | SAND AND GRAVEL PITS, TOWNSHIP OF EAST ZORRA-TAVISTOCK

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
LICENCED PITS							
1	–	Conway Consolidated Sand & Gravel	14	10	59.0 (23.9)	15-18 (5-6)	35
2	W11-13	Marshall Aggregates Pit # 1	9	11	96.0 (38.8)	40-50 (12-15)	40-45
					155.0 (62.7)		
UNLICENCED PITS*							
3	W11-108	Alf Tree	8	12		15-30 (5-9)	Slumped
4	W11-99	Wilf McKay	4	13		20-25 (6-8)	Overgrown
5	–	R. Schmidt	16	14		6-8 (2)	55-60
6	W11-12	Ferrie	16	13		8-10 (2-3)	55-60
7	W11-11	Glaves	17	13		8-10 (2-3)	55-60
8	W11-8	Hugh	22	9		10-20 (3-6)	30
9	S11-69	Unknown	35	9		12 (4)	Overgrown

* Abandoned pits or wayside pits operating on demand under authority of a permit.

TABLE 3 | SELECTED SAND AND GRAVEL RESOURCE AREAS, TOWNSHIP OF ZORRA-TAVISTOCK

1 DEPOSIT NO.	2 UNLICENCED AREA Acres (Hectares)	3 CULTURAL SETBACKS Acres (Hectares)	4 EXTRACTED AREA Acres (Hectares)	5 AVAILABLE AREA Acres (Hectares)	6 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	7 AVAILABLE AGGREGATE Millions of Tons (Tonnes)
1a	70 (28)	15 (6)	0 (0)	55 (22)	15 (5)	2 (2)
1b	190 (77)	35 (14)	0 (0)	155 (63)	15 (5)	6 (5)
2a	55 (22)	20 (8)	0 (0)	35 (14)	25 (8)	2 (2)
2b	190 (77)	95 (38)	5 (2)	90 (36)	25 (8)	6 (5)
3	90 (36)	10 (4)	6 (2)	74 (30)	10 (3)	2 (2)
	600 (243)	175 (71)	11 (4)	410 (166)		18 (16)

N.B. Minor variations in above table are due to rounding of data.

TABLE 4 | TOTAL IDENTIFIED BEDROCK RESOURCES, TOWNSHIP OF EAST ZORRA-TAVISTOCK

1 DRIFT THICKNESS Feet (Metres)	2 FORMATION	3 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	5 ORIGINAL TONNAGE Millions of Tons (Tonnes)
25-50 (8-15)	Detroit River Group (Lucas Formation)	20 (6)	35 (14)	2 (2)
25-50 (8-15)	Detroit River Group (Amherstburg Formation)	60 (18)	1470 (600)	320 (290)
			1500 (610)	320 (290)
0-3 (0-1)	Bois Blanc Formation	30 (9)	30 (12)	3 (3)
3-25 (1-8)		30 (9)	680 (275)	73 (66)
25-50 (8-15)		30 (9)	1770 (720)	191 (173)
			2480 (1000)	265 (240)
0-3 (0-1)	Bass Islands Formation	55 (17)	25 (10)	5 (4)
3-25 (1-8)		55 (17)	135 (55)	27 (24)
25-50 (8-15)		55 (17)	115 (46)	23 (21)
			275 (111)	55 (50)
			4250 (1720)	640 (580)

N.B. Minor variations in above table are due to rounding of data.

TABLE 5 | QUARRIES, TOWNSHIP OF EAST ZORRA-TAVISTOCK

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)

– NONE –

TABLE 6 | SELECTED BEDROCK RESOURCE AREAS, TOWNSHIP OF EAST ZORRA-TAVISTOCK

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 UNLICENCED AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED WORKABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)

– NONE –

TABLE 7 | SUMMARY OF TEST HOLE DATA, TOWNSHIP OF EAST ZORRA-TAVISTOCK

Test Hole Number: EZ-TH-1

Location: Lot 16, Con. 9

Elevation: Approximately 1060 feet (323 m) a.s.l.

Date: October 15, 1980

DEPTH feet (metres)	DESCRIPTION
5.0 (1.5)	alluvium and clay with small lenses of dirty sand
10.0 (3.0)	clean fine to medium sand with silt and clay lenses, some fine gravel
15.0 (4.6)	clean coarse sand graded to a clean fine sand with some fine gravel
20.0 (6.1)	a thin seam of clean medium sand overlying dark grey clay till
25.0 (7.6)	a thin seam of clean medium sand overlying dark grey clay till

Test Hole Number: EZ-TH-2

Location: Lot 16, Con. 9

Elevation: Approximately 1060 feet (323 m) a.s.l.

Date: October 15, 1980

DEPTH feet (metres)	DESCRIPTION
5.0 (1.5)	clean fine sand
10.0 (3.0)	clean fine to medium sand
15.0 (4.6)	clean medium sand overlying pink clay till
20.0 (6.1)	pink, sandy and silty clay till overlying dark grey clay till

TABLE 7 SUMMARY OF TEST HOLE DATA, TOWNSHIP OF EAST ZORRA-TAVISTOCK

Test Hole Number: EZ-TH-3

Location: Lot 5, Con. 14

Elevation: Approximately 1025 feet (312 m) a.s.l.

Date: October 15, 1980

DEPTH feet (metres)	DESCRIPTION
5.0 (1.5)	light brown, silty sandy till
10.0 (3.0)	no sample, very hard material
15.0 (4.6)	grey clay with occasional pebbles overlying light brown silt
20.0 (6.1)	light brown fine silt
25.0 (7.6)	silty medium sand
30.0 (9.1)	coarse sand with fine to medium angular to subrounded gravel
35.0 (10.7)	clean medium to coarse sand with fine angular to subrounded gravel

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APPENDIX B - GLOSSARY

ABRASION RESISTANCE

Tests such as the Los Angeles Abrasion Test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

ABSORPTION CAPACITY

Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

AGGREGATE

Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

CAMBRIAN

The first Period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago; the Cambrian precedes the Ordovician Period.

CLAST

An individual constituent, grain, or fragment of a sediment or rock, produced by the mechanical weathering of a large rock mass. Synonyms include particle and fragment.

DELETERIOUS LITHOLOGY

A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone, and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

DEVONIAN

A Period of the geological past thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

DIRT

See fines.

DOLOSTONE

A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

DRIFT

A general term for all unconsolidated rock debris transported from one place and deposited in another; distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

DRUMLIN

A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were deposited beneath an advancing ice sheet, and were shaped by its flow.

EOLIAN

Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

FINES

A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.074 mm). Also described informally as "dirt", these particles are in the silt- and clay-size range.

GLACIAL LOBE

A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced and retreated numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

GRADATION

The proportion of material of each particle size or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder		>-256 mm
Gravel	cobble	64-256 mm
Gravel	pebble	4-64 mm
Gravel	granule	2-4 mm
Sand	coarse	.5-2 mm
	medium	.25-.5 mm
	fine	.074-.25 mm
Silt, clay		<.074 mm

GRANULAR BASE COURSE

Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability, and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

H.L. (HOT-LAID OR ASPHALTIC AGGREGATE)

Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3, and 4), or as binder course (H.L. 2, 6, and 8) used to bind the surface course to the underlying granular base course.

LITHOLOGY

The description of rocks on the basis of such characteristics as color, structure, mineralogic composition, and grain size. Generally, the description of the physical character of a rock.

MELTWATER CHANNEL

A drainage way, usually terraced, produced by water flowing away from a melting glacier margin.

ORDOVICIAN

An early peiod of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

PALEOZOIC ERA

One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago. The Paleozoic Era (or Ancient Life Era) is subdivided into six geologic Periods, of which only four (Cambrian, Ordovician, Silurian, and Devonian) can be recognized in southern Ontario.

PLEISTOCENE

An Epoch of the recent geological past including the time from approximately 1.8 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity.

POSSIBLE RESOURCE

Estimates of mineral aggregate material based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples of measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

SHALE

A fine-grained, sedimentary rock formed by the consolidation of clay, silt, or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone, and mudstone.

SILURIAN

An early Period of the Paleozoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

SOUNDNESS

The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

TILL

Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

WISCONSINAN

Pertaining to the last glacial stage of the Pleistocene Epoch in North America. It began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Winsconsinan Stage.

APPENDIX C - GEOLOGY OF SAND AND GRAVEL DEPOSITS

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 7000 to 85 000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and they can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

ICE-CONTACT TERRACES (ICT)

These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous due to extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive due to the variability of the deposits both in terms of quality and grain-size distribution.

KAMES (K)

Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and cross-bedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good-quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the presence of excess fines (silt- and clay-sized particles).

ESKERS (E)

Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. They vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout southern Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

UNDIFFERENTIATED ICE-CONTACT STRATIFIED DRIFT (IC)

This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits due to their lack of continuity and grain-size variability. They are given a qualita-

tive rating based on existing pit and other subsurface data.

OUTWASH (OW)

Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. They occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain-size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

ALLUVIUM (AL)

Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amount of crushable aggregate in alluvial deposits in low, and it has generally low value due to the presence of excess silt- and clay-sized material. There are no large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

GLACIOLACUSTRINE BEACH DEPOSITS (LB)

These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the underlying material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

GLACIOLACUSTRINE DELTAS (LD)

These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

GLACIOLACUSTRINE PLAIN (LP)

The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources due to their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

END MORAINES (EM)

These are belts of glacial drift deposited at, and parallel to, glacier margins. They commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best resource areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

WINDBLOWN FORMS (WD)

Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from

and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments are almost invariably composed of fine to coarse sand and are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

APPENDIX D - GEOLOGY OF BEDROCK DEPOSITS

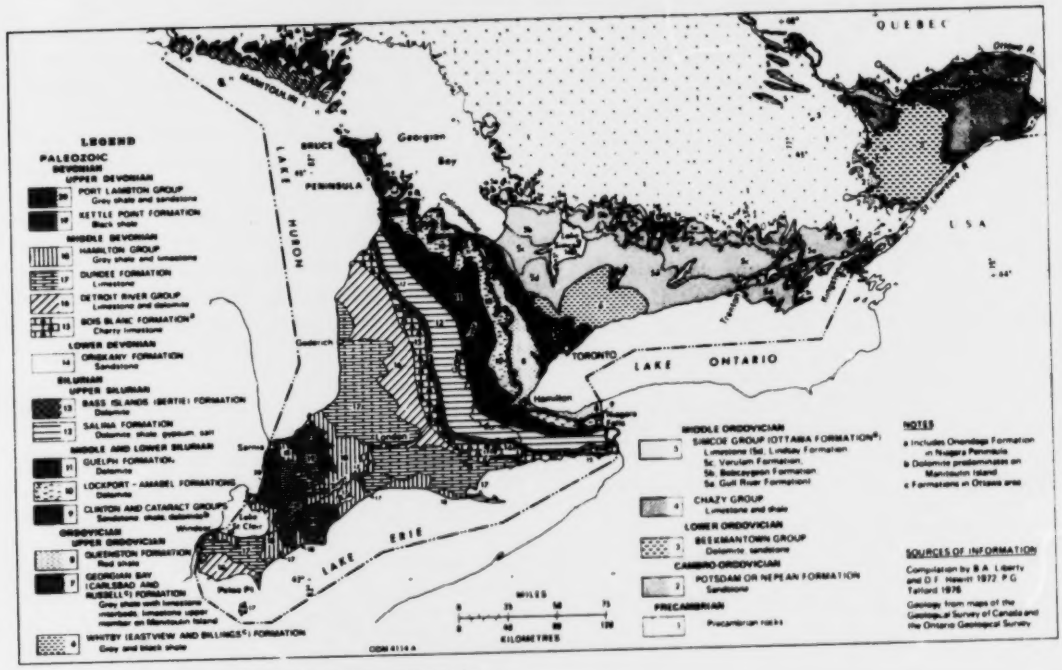

Figure 2 - Bedrock Geology of Southern Ontario

BEDROCK SUITABLE FOR CRUSHED STONE PRODUCTS

BASS ISLANDS FORMATION (UPPER SILURIAN)

(Includes the Bertie Formation of the Niagara Peninsula) Composition: Medium- to massive-bedded, aphanitic, brown dolostone with shaly partings. Thickness: 35 to 60 feet (11-18m) near Hagersville. Uses: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville, and Dunville. Los Angeles Abrasion Test: 17-35% loss; Absorption: 1.4%. Shaly parts are unsuitable for aggregate due to high soundness losses.

BOBCAYGEON FORMATION (MIDDLE ORDOVICIAN)

Composition: Compact, homogeneous, medium- to thin-bedded, fine-grained limestone with some argillaceous and shaly partings. Thickness: The lower unit is 40 to 72 feet (12 to 22 m) thick in the east and the remainder of the formation is 40 feet (12 m). Uses: Quarried at Kirkfield and Marysville for crushed stone. The Bobcaygeon Formation has consistently acceptable quality for granular base course materials and concrete.

BOIS BLANC FORMATION (LOWER-MIDDLE DEVONIAN)

Composition: Brownish grey, medium-crystalline, medium- to thin-bedded, cherty limestone, commonly fossiliferous. Limestone may be silty or sandy in places. Thickness: 9 to 200 feet (3 to 61 m). Uses: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. High chert content makes much of the material unsuitable for concrete aggregate. Los Angeles Abrasion

Test: 14-28% loss; Soundness Test: 4-10% loss; Absorption: 0.7-2.0%.

DUNDEE FORMATION (MIDDLE DEVONIAN)

Composition: Fine- to medium-crystalline, brownish grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. Thickness: 60 to 160 feet (18 to 49 m). Uses: Quarried near Port Dover and Pelee Island for crushed stone. Used at St. Marys for portland cement. Los Angeles Abrasion Test: 22-32% loss; Absorption: 0-4%.

GULL RIVER FORMATION (MIDDLE ORDOVICIAN)

Composition: Member A: thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone with a maximum thickness of 60 feet (18 m). Members B and C are dense, aphanitic limestones with argillaceous dolostone interbeds. Uses: Quarried at Kirkfield, Victoria County, and Uthoff for crushed stone. The product is generally fresh and compact with good cubic-shaped factor, low clay content, low absorption, and low soundness losses. Smooth particle surfaces may cause adhesion problems for asphalt. There is some alkali reactivity in a few of the layers.

LOCKPORT AND AMABEL FORMATIONS (MIDDLE SILURIAN)

Composition: Amabel Formation (Waterdown to the Bruce Peninsula): massive, fine crystalline dolostone, with reef facies dolostone near Georgetown. Lockport Formation (lateral facies equivalent to the Amabel Formation from Watertown to Niagara Falls): thin- to massive-bedded, fine- to medium-grained dolostone. Thickness: Amabel Formation: maximum observed thickness of 84 feet (26 m). Lockport Formation: up to 130 feet (40 m). Uses: The Lockport and Amabel Formations have been used to produce lime, crushed stone, and building stone throughout their area of occurrence, and are a valuable aggregate resource. Los Angeles Abrasion Test: 21-35% loss; Soundness Test: 2.0% loss; Absorption: 0.4-1.6%.

ONONDAGA FORMATION (MIDDLE DEVONIAN)

(Equivalent to the Detroit River Group, with a textural change) Composition: Edgecliffe Member: medium-bedded, fine- to medium-grained, dark grey cherty limestone with an estimated thickness of 25 to 30 feet (8 to 9 m). Clarence Member: massive-bedded, dark grey brown, fine-grained, very cherty limestone having an estimated thickness of 26 feet (8 m). Moorehouse Member: medium-bedded, dark grey brown or purplish brown, fine- to coarse-grained, variably cherty limestone with an estimated thickness of 15 to 25 feet (5 to 8 m). Uses: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High chert content makes much of the material unsuitable for concrete aggregate.

OTTAWA FORMATION (MIDDLE ORDOVICIAN)

Composition: Lower Phase (Lowville and Pamela Beds): shale, some sandstone and dolostone. Thickness: 100 feet (30 m). Middle Phase (Hull, Rockland, and Leray Beds): pure, thick-bedded, crystalline limestone. Thickness: 150 feet (46 m) near Ottawa. Upper Phase (Cobourg and Sherman Falls Beds): pure and impure crystalline limestone with few to numerous shaly partings, 450 to 475 feet (137 to 145 m) thick near Ottawa. Uses: The Leray, Rockland, and Hull Beds have been quarried extensively for crushed stone and for building stone. In addition, the Hull Beds are an excellent source of lime for cement production and agricultural uses.

OXFORD FORMATION (LOWER ORDOVICIAN)

Composition: Medium- to thick-bedded, grey dolostone, with some shaly partings. Thickness: 240 feet (73 m). Uses: Quarried for crushed stone (road and concrete aggregate) at Ottawa, Brockville, and Smiths Falls.

BEDROCK SUITABLE FOR LIME PRODUCTION AND OTHER CHEMICAL USES.

DETROIT RIVER GROUP (MIDDLE DEVONIAN)

(Equivalent to the Onondaga Formation in the Niagara Peninsula, with a textural change). Composition: Near Beachville, the group consists of medium- to micro-crystalline, medium-bedded, high purity limestone. It grades northwards near St. Marys to soft, evenly bedded, fine-grained dolostone with bituminous laminae. Massive, porous, reef facies material also occurs to the north (Formosa Reef Limestone). Thickness: 100 feet (30 m) at Beachville, 350 feet (107 m) at Clinton. Uses: The most important

source of high purity limestone in Ontario is the Lucas Formation of the Detroit River Group at Beachville. Detroit River limestone produces 80% of Ontario's cement. Its dolomitic reefal facies is also important for lime production to the north. It is generally unsuitable for crushed stone. The Anderdon Member of the Lucas formation is quarried at Amherstburg for crushed stone.

GRENVILLE MARBLE (PRECAMBRIAN)

Composition: Recrystallized white limestone and dolostone, fine- to coarse-grained, usually of high chemical purity. Uses: Lime production, but also in small amounts for terrazo chips, poultry grit, decorative stone, and building stone.

GUELPH FORMATION (MIDDLE SILURIAN)

Composition: Aphanitic- to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies dolostone of high chemical purity. The Guelph Formation and the underlying Amabel Formation have a combined thickness of 200 feet (61 m) on the Niagara Peninsula and more than 400 feet (122 m) on the Bruce Peninsula. Uses: The main use is for dolomitic lime in the construction industry. It is quarried at Glen Christie and Guelph.

LINDSAY FORMATION (MIDDLE ORDOVICIAN)

Composition: Lower Member: fine-crystalline, rubbly, nodular, weathering limestone. Upper Member: grey calcareous claystone with shaly partings and bioclastic layers. The rock is "soft" and weathers to rubble. Both members are characterized by low dolomite content and by numerous clayey partings. Uses: Quarried at Picton, Ogden Point, Colborne, and Bowmanville for lime. It is generally unsuitable for crushed stone, concrete aggregate, or granular base course.

VERULAM FORMATION (MIDDLE ORDOVICIAN)

Composition: Fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The rock is not resistant to erosion and commonly weathers to rubble. Thickness: 200-300 feet (61-91 m). Uses: Quarried at Picton, Ogden Point, and Mara Township for lime. It is unsuitable for crushed stone due to clay impurities and many clayey interbeds, low abrasion resistance. High soundness losses and poor freeze-thaw resistance.

BEDROCK SUITABLE FOR BRICK AND TILE MANUFACTURE

GEORGIAN BAY FORMATION (UPPER ORDOVICIAN)

(Formerly known as the Meaford-Dundas and Blue Mountain shales in the Toronto and Bruce Peninsula areas). Composition: Soft, fissile, blue grey shale with limey or sandy lenses in a few places. Thickness: 640 feet (195 m) at Toronto. Uses: Five producers in Metro Toronto and Cooksville produce brick and structural tile (Guillet 1967). Lightweight aggregate is also produced at Streetsville by heat expansion of the shale.

HAMILTON GROUP (MIDDLE DEVONIAN)

Composition: Grey shale with interbeds of crystalline and cherty limestone. The Group has six formations. Only the Arkona is of commercial value. It is a soft, light grey, calcareous shale which is plastic and easily worked when wet. Thickness: 80 to 300 feet (24 to 91 m). Uses: The Arkona Formation is extracted at Thedford and near Arkona for production of drainage tile and brick.

QUEENSTON FORMATION (UPPER ORDOVICIAN)

Composition: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. Thickness: 400 to 500 feet (122 to 152 m). Uses: There are 12 large shale quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa (Guillet 1967). All produce brick for construction. The Queenston Formation is the most important source material for brick manufacture in the Province.

BEDROCK SUITABLE FOR OTHER INDUSTRIAL PRODUCTS

NEPEAN (POTSDAM) FORMATION (CAMBRO-ORDOVICIAN)

Composition: Creamy, coarse-grained, silica sandstone. Uses: Quarried throughout its area of outcrop for building stone, decorative stone, abrasives, and for glass making.

SALINA FORMATION (UPPER SILURIAN)

Composition: Grey and red shale, brown dolomite, and, in places, salt, anhydrite, and gypsum. The formation consists predominantly of evaporite deposits with up to eight members identified. Uses: Gypsum is mined at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and is produced from brine wells at Amherstburg, Windsor, and Sarnia.

WHITBY FORMATION (UPPER ORDOVICIAN)

(Formerly known as Collingwood Shale near Toronto). Composition: Brown to black fissile shale. Uses: Quarried at Bowmanville for use in cement production. Testing indicates that the Whitby Formation may produce satisfactory lightweight expanded aggregate.

Tavistock
Sebastopol
Punkeydoodles Corners
Cassel
Thames River
Canadian National
Trans Sta
Greenhouse
Cheese Factory
Poultry Farm
Orchard
Windpump
Sewage
Ditch
Airfield
PERTH CO
OXFORD CO
TP. OF E. ZORRA-TAVISTOCK
TP. OF BLANDFORD-BLENHEIM
TP. OF WILMOT
R.M. OF WATERLOO
S. EASTHOPE TP.
TP. OF ZORRA
XIX
XVIII
XVII
XVI
XV
XIV
IX
XII
1148
1136
1132
1139
1122
1113
1091
1088
1086
1082
1079
1077
1068
1176
1161
1146
16GS
18SC
28SC
22SG
21SC
25S
30S
9S
S 4 IC
S 4 OW
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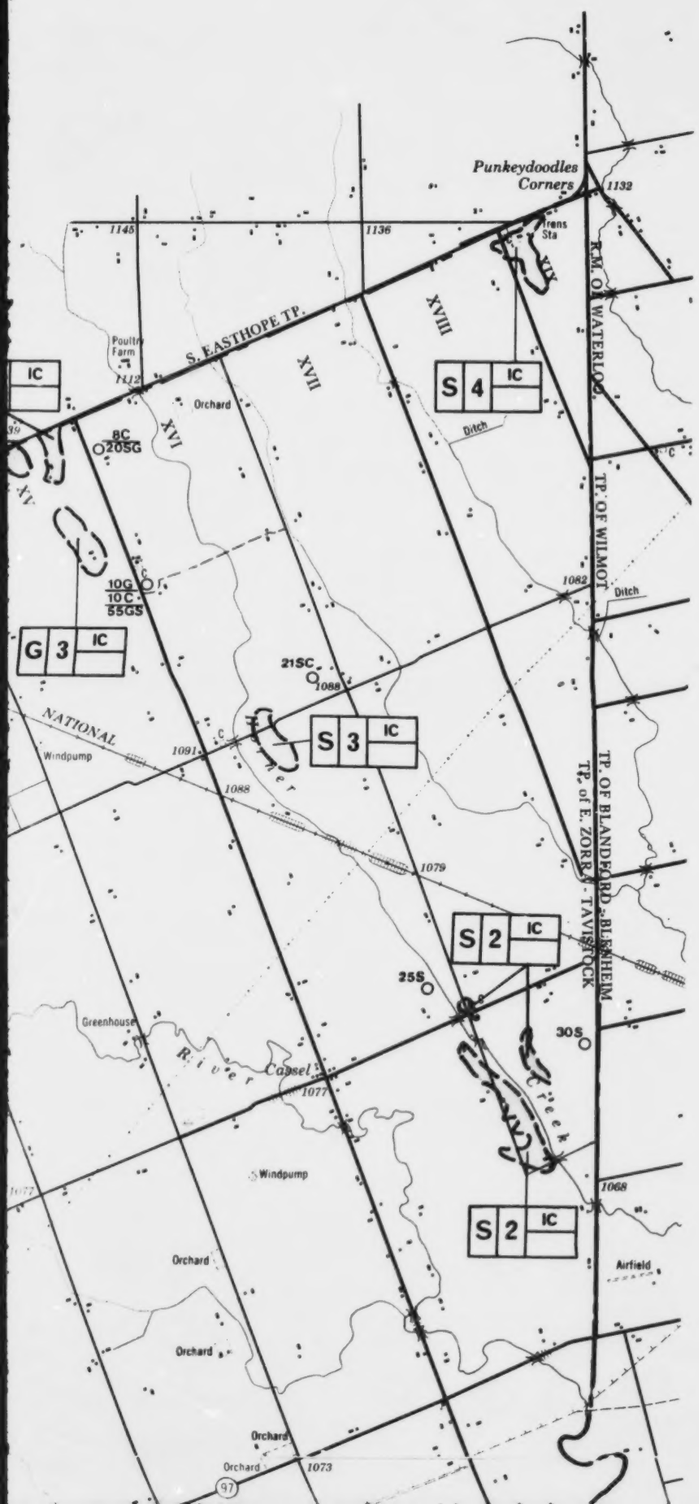
10G 10C 35GS
10G
GP
59
N



Ministry of Natural Resources

Ontario

Hon. Alan W. Pope
Minister

W.T. Foster
Deputy Minister

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

TOWNSHIP OF EAST ZORRA-TAVISTOCK

OXFORD COUNTY
MAP 1
DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Scale: 1:50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: 40 P/2, 40 P/7

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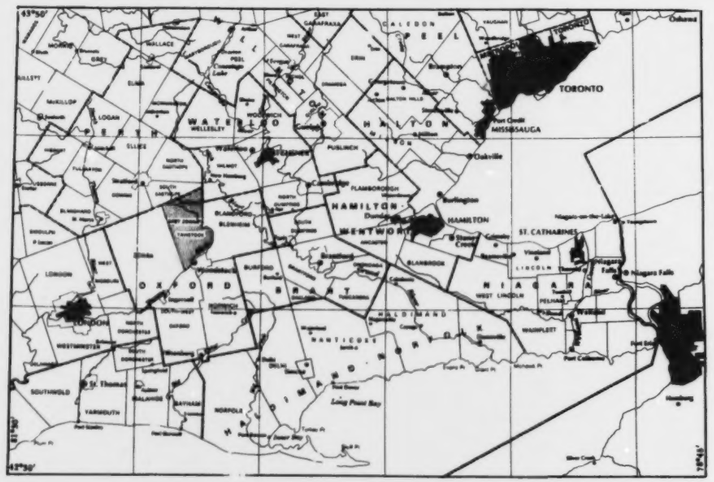


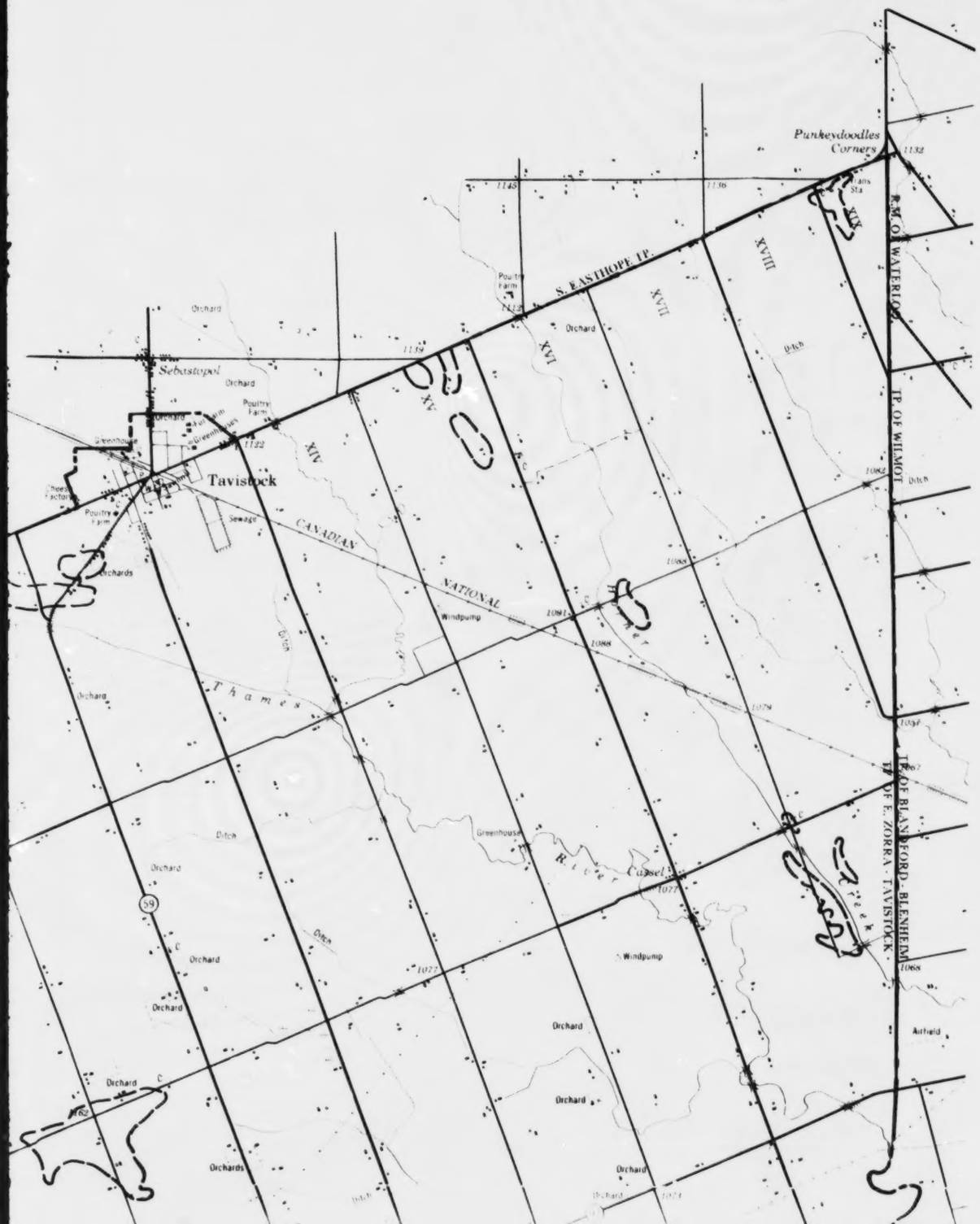
SYMBOLS
(Some symbols may not apply to this map)

- Geological and aggregate thickness boundary. Shading indicates deposit area.
- Approximate boundary of buried deposit. Shading indicates deposit area.

DEPOSIT SYMBOL
(Continued)

Thickness Class

Punkeydoodles Corners
1132
1136
1146
Trans Sta
XIX
R.M. OF WATERLOO
S. EASTHOPE TP.
XVIII
XVII
XVI
XV
XIV
Poultry Farm
1112
Orchard
1139
Ditch
Sebastopol
Orchard
Poultry Farm
Orchard
Fur Farm
Greenhouses
1122
Greenhouse
Tavistock
Cheese Factory
Poultry Farm
Sewage
CANADIAN NATIONAL
1175
GP
Orchards
Ditch
1088
1091
Windpump
Ditch
Thames River
1088
1079
1057
TP. OF WILMOT
Ditch
1082
TP. OF BLANDFORD - BLENHEIM
TP. OF E. ZORRA - TAVISTOCK
1067
Orchard
Greenhouse
Cassel Creek
1077
1068
Windpump
Airfield
Orchard
Orchard
Orchard
Orchard
1161
59
Orchard
Orchard
Ditch
1146
Windpump
Ditch
TP. OF E. ZORRA - TAVISTOCK
TP. OF ZORRA
Orchard
1162
Windpump
Orchards
Orchard
Orchard
1072
N
EA
S
OM



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TOWNSHIP OF EAST ZORRA-TAVISTOCK

OXFORD COUNTY

MAP 2

SELECTED SAND AND GRAVEL RESOURCE AREAS

Scale: 1:50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: **40 P/2, 40 P/7**

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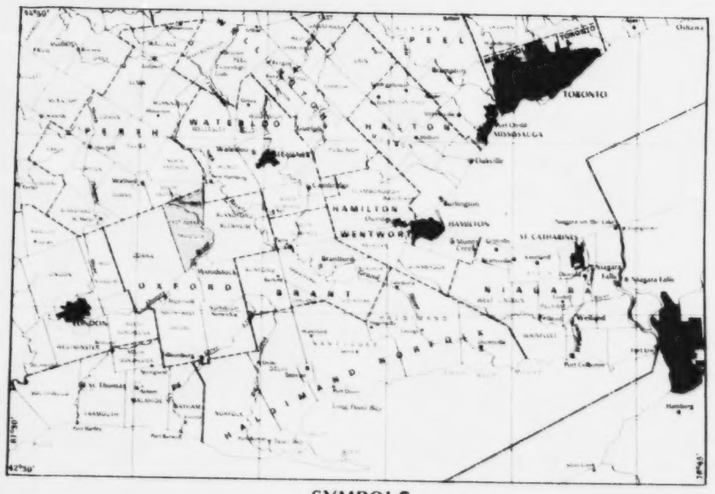
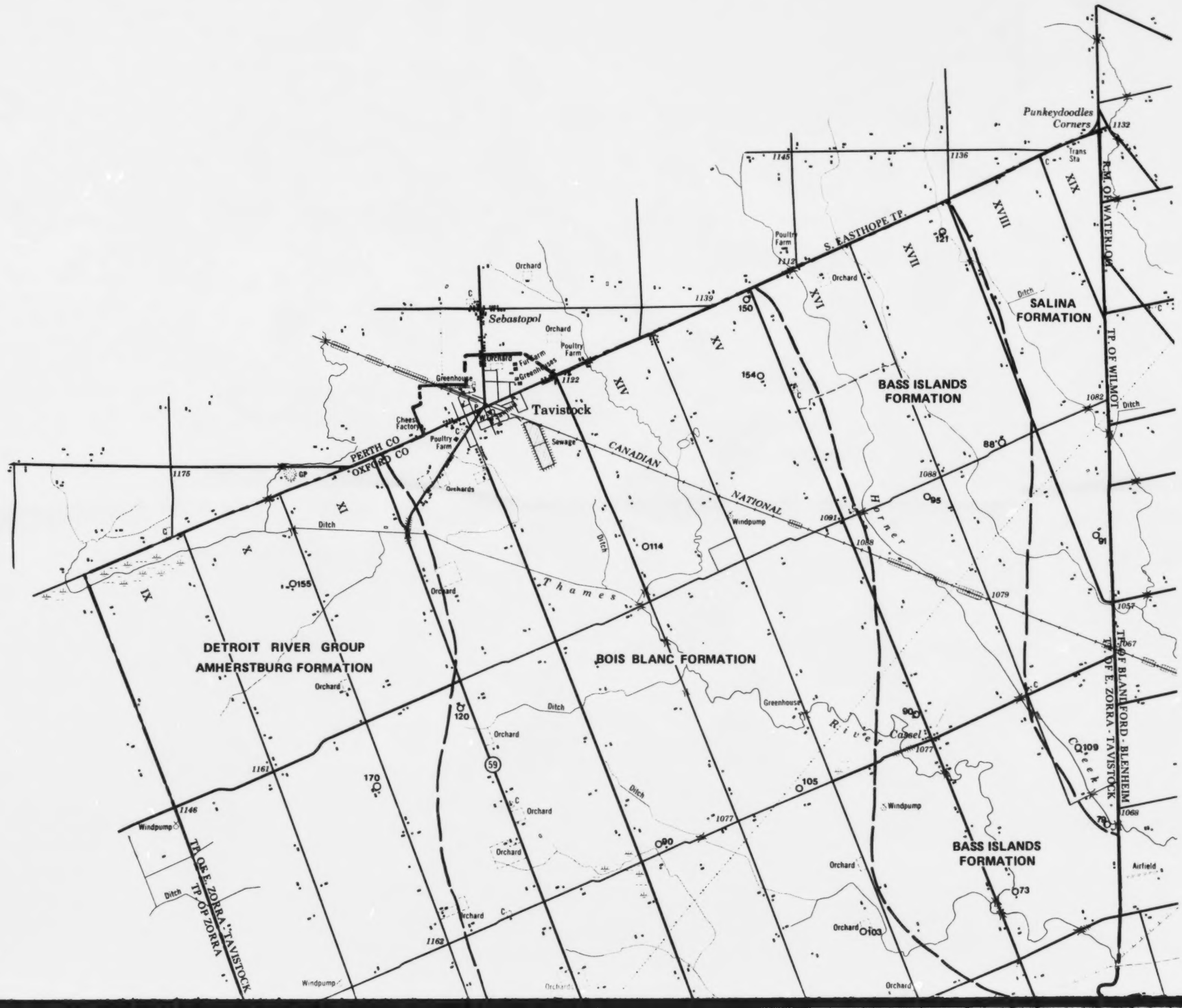
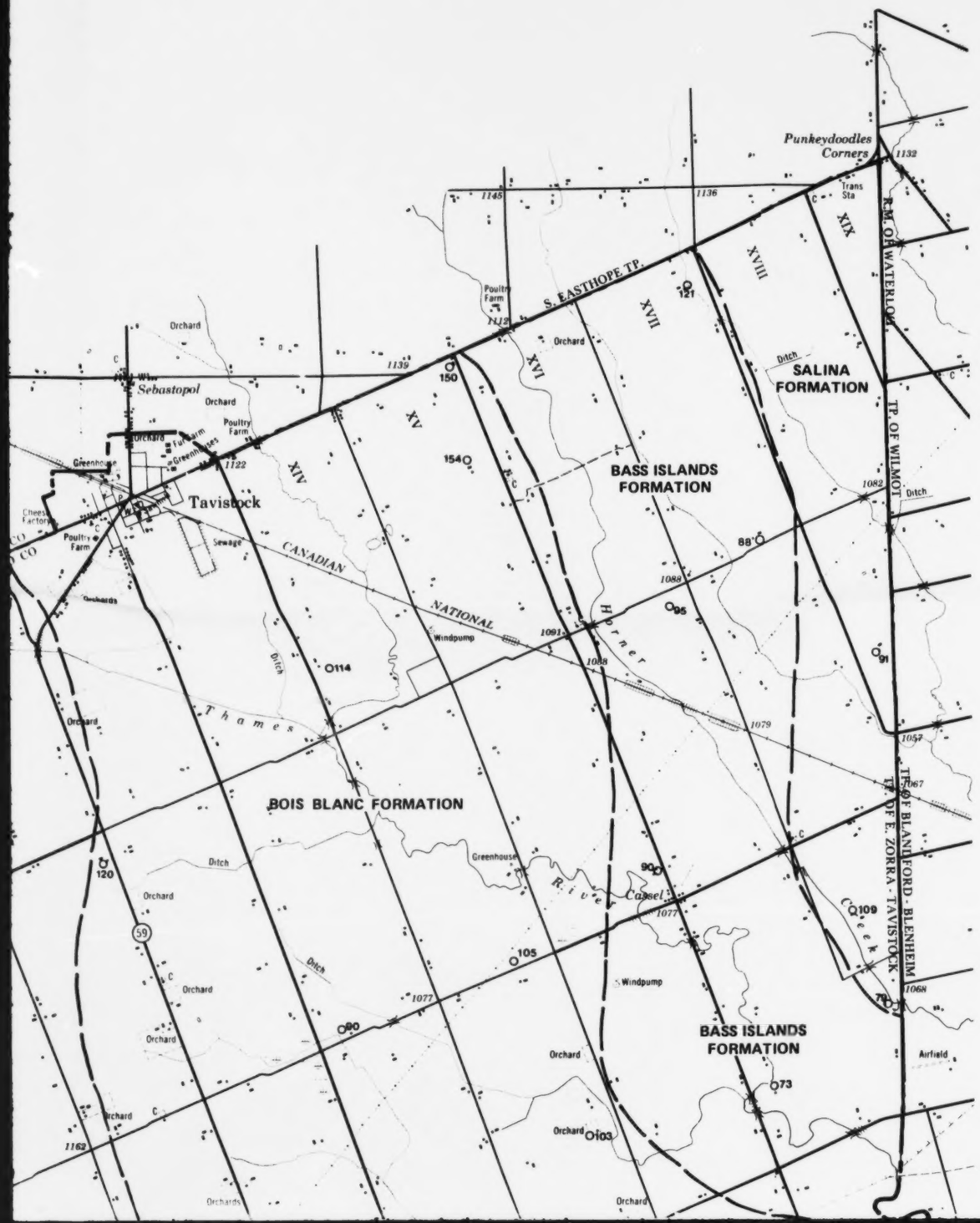


SYMBOLS

(Some symbols may not apply to this map)

- Geological and aggregate thickness boundary.
- Approximate boundary of buried deposit.
- Selected sand and gravel resource area. Primary significance. Deposit number see Table 3
- Selected sand and gravel resource area. Secondary significance.
- Selected sand and gravel resource area. Tertiary significance.


Punkeydoodles Corners
1132
1145
1136
Trans Sta
S. EASTHOPE TP.
R.M. OF WATERLOO
TP. OF WILMOT
Poultry Farm
1112
Orchard
XVIII
XIX
XVII
XVI
XV
XIV
121
150
154
SALINA FORMATION
BASS ISLANDS FORMATION
Ditch
1082
Sebastopol
1139
Greenhouse
Fuel
Greenhouses
1122
Tavistock
Cheese Factory
Poultry Farm
Sewage
CANADIAN NATIONAL
PERTH CO
OXFORD CO
1175
GP
Orchards
XI
X
IX
O155
O114
Windpump
1088
1091
1088
Horner
O95
O91
1079
1057
1067
TP. OF BLANDFORD - BLENHEIM
TP. OF E. ZORRA - TAVISTOCK
Thames River
DETROIT RIVER GROUP
AMHERSTBURG FORMATION
BOIS BLANC FORMATION
120
59
Greenhouse
Canagagigue Creek
O109
1077
1068
170
1161
1146
Windpump
TP. OF E. ZORRA - TAVISTOCK
TP. OF ZORRA
O105
O90
O73
O103
Airfield
1162
Windpump
Orchard
EA
© OMN



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ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

TOWNSHIP OF EAST ZORRA-TAVISTOCK

OXFORD COUNTY

MAP 3

BEDROCK RESOURCES

Scale: 1:50 000

Mile 1 0 1 Mile
Metres 1000 0 1 Kilometre

NTS Reference: 40 P/2, 40 P/7

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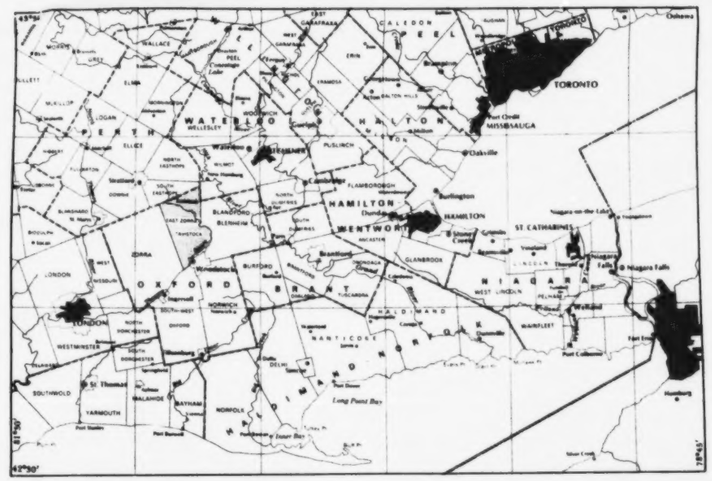


LEGEND

PALEOZOIC

DEVONIAN

MIDDLE DEVONIAN

DETROIT RIVER GROUP

LUCAS FORMATION

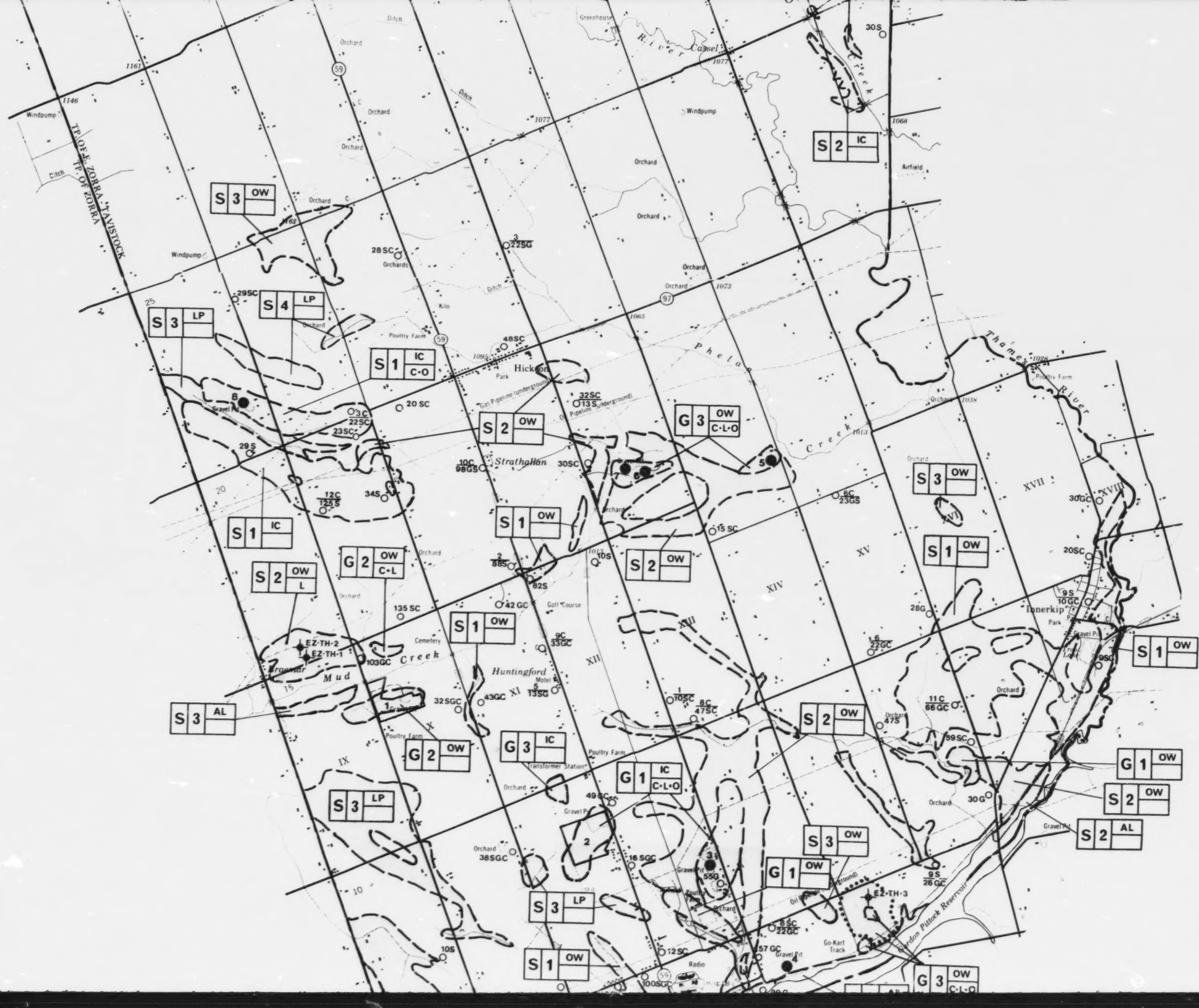
Limestone

AMHERSTBURG FORMATION

Limestone and dolostone

LOWER DEVONIAN

Limestone



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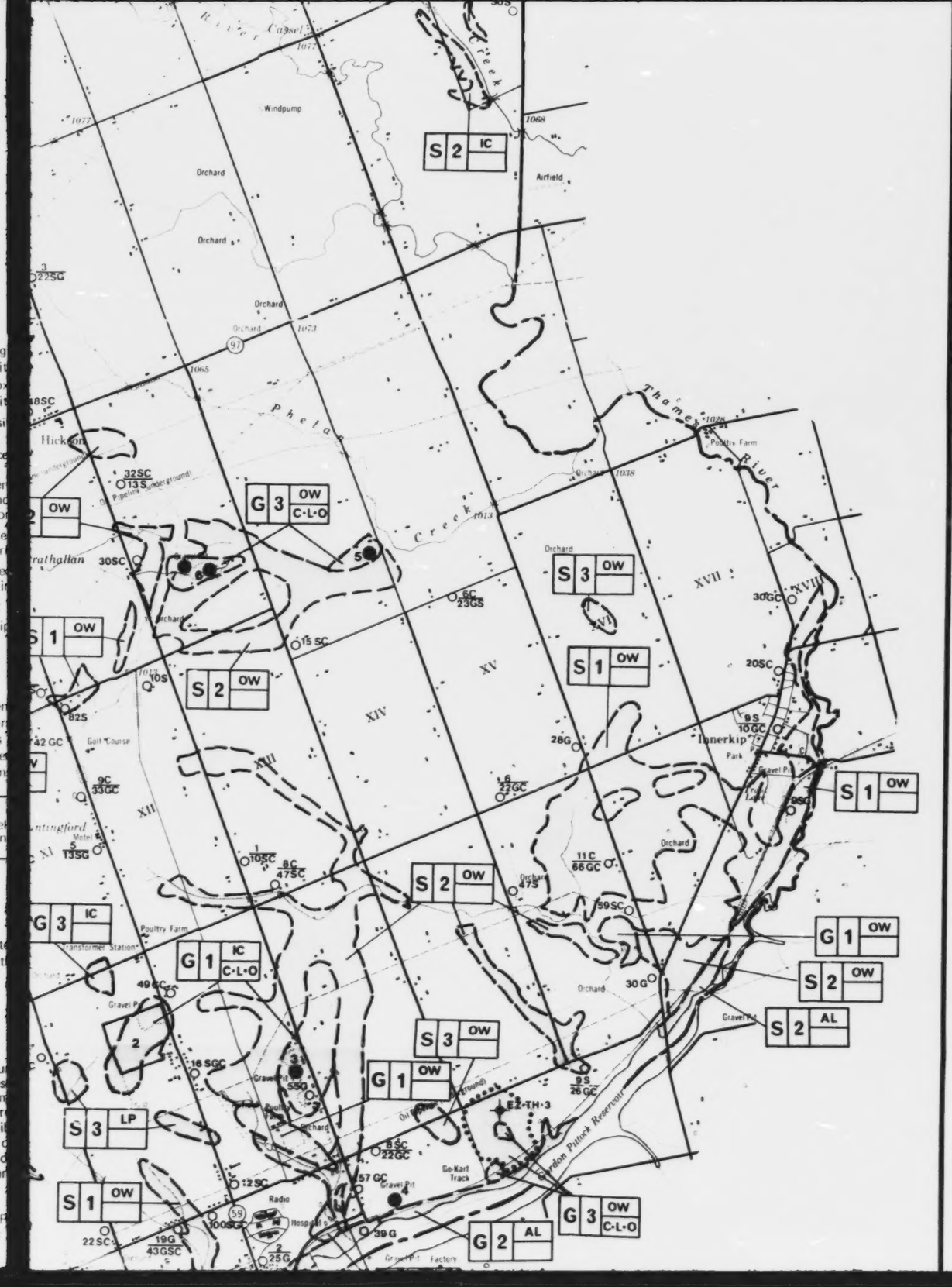

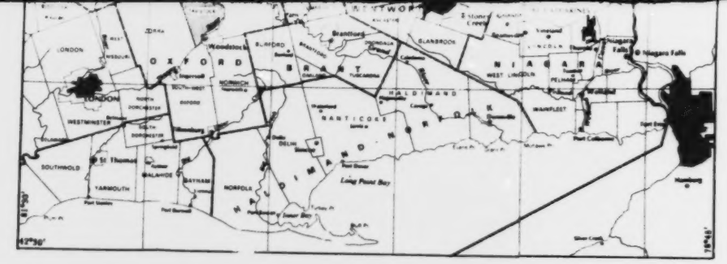

SYMBOLS

(Some symbols may not apply to this map)

- Geological and aggregate thickness boundary. Shading indicates deposit area.
- Approximate boundary of buried deposit. Shading indicates deposit area.
- S 1 IC C·L — Deposit symbol: see below.
- 3 — Licenced property boundary; Property number: see Table 2.
- 4 — Unlicenced sand or gravel pit*; Property number: see Table 2. *Abandoned pit or wayside pit operating on demand under authority of a permit.
- EZ-TH-2 — Selected test hole location; Identification number: see Table 7. (Ontario Geological Survey, Ministry of Natural Resources.)
- 6 / 23 GS — Selected drilling location indicating thickness of overburden overlying reported thickness of granular materials (in feet). (Note: S - sand, G - gravel, T - till)
- Municipal boundary.

DEPOSIT SYMBOL

Deposits are identified by gravel content, thickness class, deposit type and quality indicators. Gravel content is expressed as percentage of crushable material. Classes are based on potential aggregate tonnage per acre and are designated numerically. Type refers to geologic origin. Quality modifiers indicate variations in grain size distribution and lithology.

Gravel Content	Thickness Class	Geological Type
		Quality Indicators

Gravel Content

G	Greater than 35% gravel.
S	Less than 35% gravel.

DEPOSIT SYMBOL (Continued)

Thickness Class

Class	Average Thickness in feet (metres)	Tons per acre (Tonnes per hectare)
1	greater than 20 (> 6)	greater than 50,000 (>112 000)
2	10-20 (3-6)	25,000-50,000 (56 000 - 112 000)
3	5-10 (1.5-3)	12,500-25,000 (28 000 - 56 000)
4	less than 5 (< 1.5)	less than 12,500 (<28 000)

Geological Type

IC	Undifferentiated Ice-Contact Stratified Drift	OW	Outwash
ICT	Ice-Contact Terrace	LB	Lacustrine Beach
K	Kame	LP	Lacustrine Plain
E	Esker	LD	Lacustrine Delta
EM	End Moraine	AL	Older Alluvium
		WD	Windblown Forms

(see Appendix C for descriptions of Geological Types.)

Quality Indicators

	If blank, no known limitations present
C	Clay and/or silt (fines) present in objectionable quantities
L	Deleterious lithologies present
O	Oversize particles or fragments present in objectionable quantities

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.
Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.
Selected drilling data from the Ontario Ministry of the Environment and the Petroleum Resources Section, Ontario Ministry of Natural Resources.

Geology by: W.R. Cowan, 1975.
P.F. Karrow, 1971.

Compilation and Drafting by: Staff of the Aggregate Assessment Office.

Issued 1982.

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This map is to accompany O.G.S. Aggregate Resources Inventory Paper 63.

TP. OF ZORRA
ZORRA TAVISTOCK
Ditch
Orchard
Windpump
Orchards
Kiln
Poultry Farm
Hickson
Park
Gas Pipeline (underground)
Oil Pipeline (underground)
Gravel Pit
Strathallan
Golf Course
Cemetery
Mud Creek
Huntingford
Motel
Transformer Station
Radio
Hospital
Factory
Home for Aged
Sewage Plant
WOODSTOCK
Phelps Creek
Thames River
Ingersoll
Innerkip
Park
Go Kart Track
Gordon Pittock Reservoir
Pond
Tiles
1b
1a
2a
2b
3
4
1
2
8
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97
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XI
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XV
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XVIII
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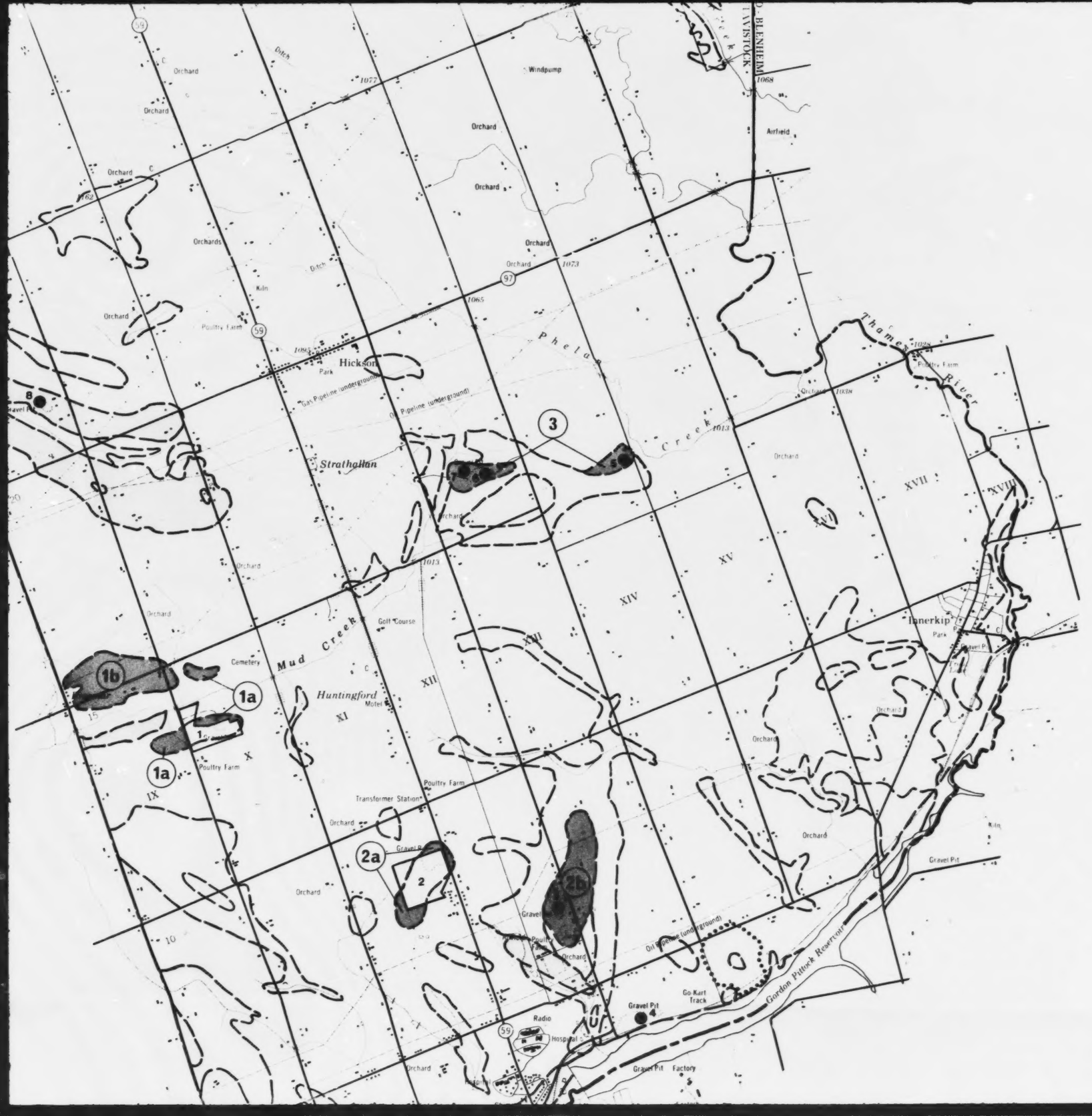

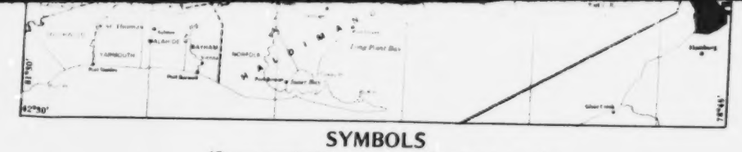

SYMBOLS

(Some symbols may not apply to this map)

- Geological and aggregate thickness boundary.
- Approximate boundary of buried deposit.
- Selected sand and gravel resource area; Primary significance; Deposit number: see Table 3.
- Selected sand and gravel resource area. Secondary significance.
- Selected sand and gravel resource area; Tertiary significance.
- 2 — Licenced property boundary; Property number: see Table 2.
- 4 — Unlicenced sand or gravel pit*; Property number: see Table 2. *Abandoned pit or wayside pit operating on demand under authority of a permit.
- Municipal boundary.

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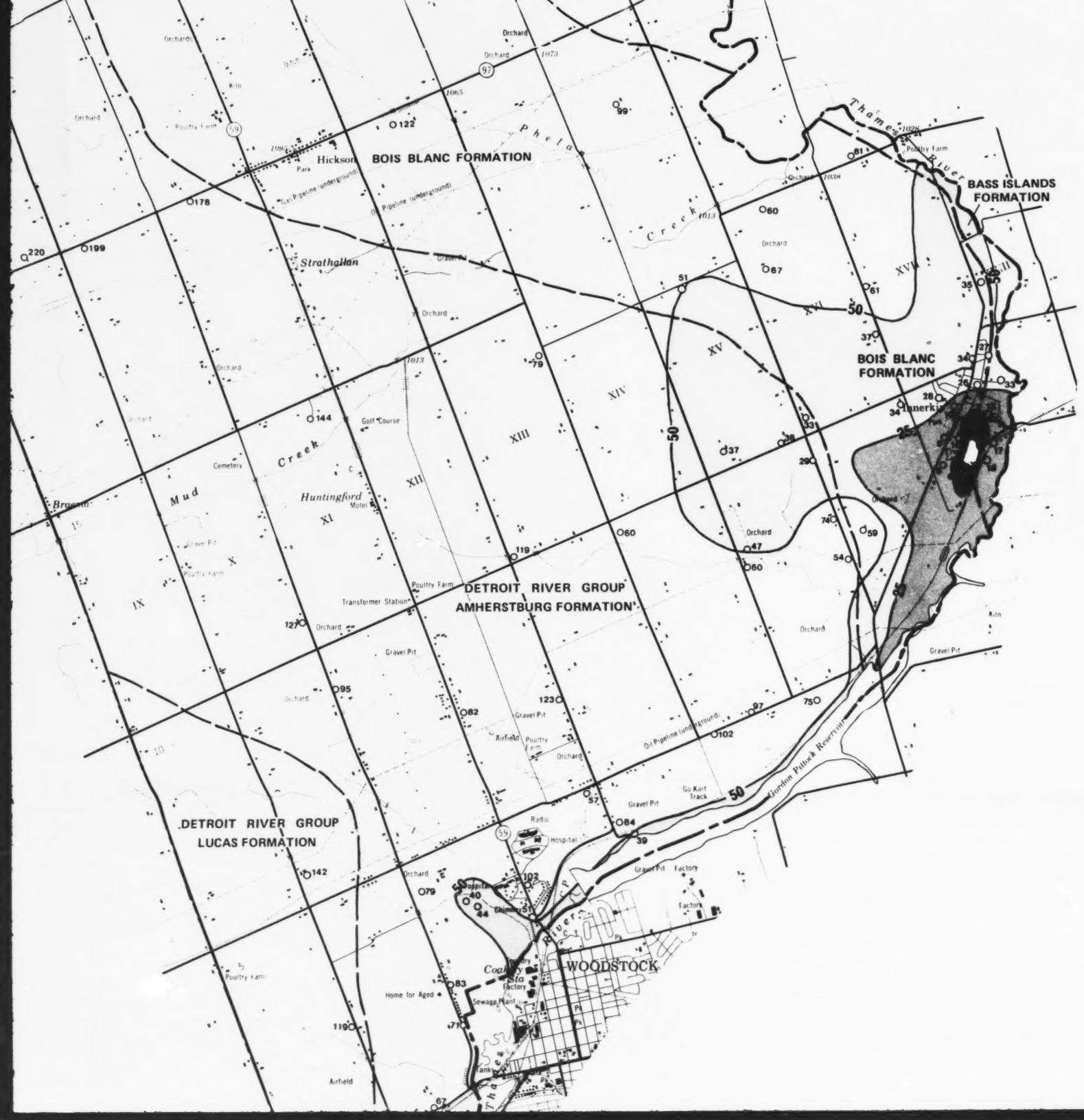
BOIS BLANC FORMATION
BASS ISLANDS FORMATION
BOIS BLANC FORMATION
DETROIT RIVER GROUP
AMHERSTBURG FORMATION
DETROIT RIVER GROUP
LUCAS FORMATION
WOODSTOCK
Strathallan
Hickson
Huntingford
Braemar
Mud Creek
Phelan Creek
Thames River
Gordon Pittock Reservoir
Gas Pipeline (underground)
Oil Pipeline (underground)
Oil Pipeline (underground)
Golf Course
Cemetery
Motel
Transformer Station
Airfield
Go Kart Track
Radio
Hospital
Home for Aged
Sewage Plant
Factory
Gravel Pit
Poultry Farm
Orchard
Kiln
Park
Tanks
Ditch
Pipeline
Creek
Thames River



AMHERSTBURG FORMATION
Limestone and dolostone

LOWER DEVONIAN

BOIS BLANC FORMATION
Cherty limestone

SILURIAN

UPPER SILURIAN

BASS ISLANDS FORMATION
Dolostone

SALINA FORMATION
Dolostone, shale, gypsum, salt

SYMBOLS

(Some symbols may not apply to this map.)

- Geological boundary.
- 25 — Drift thickness contour line (25 foot (8 m) interval).
- x — Isolated bedrock outcrop.
- Bedrock within 3 feet (1 m) of surface: see Table 4.
- Bedrock covered by 3 to 25 feet (1 m to 8 m) of overburden: see Table 4.
- Bedrock covered by 25 to 50 feet (8 m to 15 m) of overburden: see Table 4.
- (1) — Selected bedrock resource area; Deposit number: see Table 6.
- Q3 — Licenced quarry boundary; Property number: see Table 5.
- Q4 — Unlicenced quarry*; Property number: see Table 5.
  *Abandoned quarry or wayside quarry operating on demand under authority of a permit.
- 23 — Selected drilling location indicating reported depth to bedrock (in feet).
- Municipal boundary.

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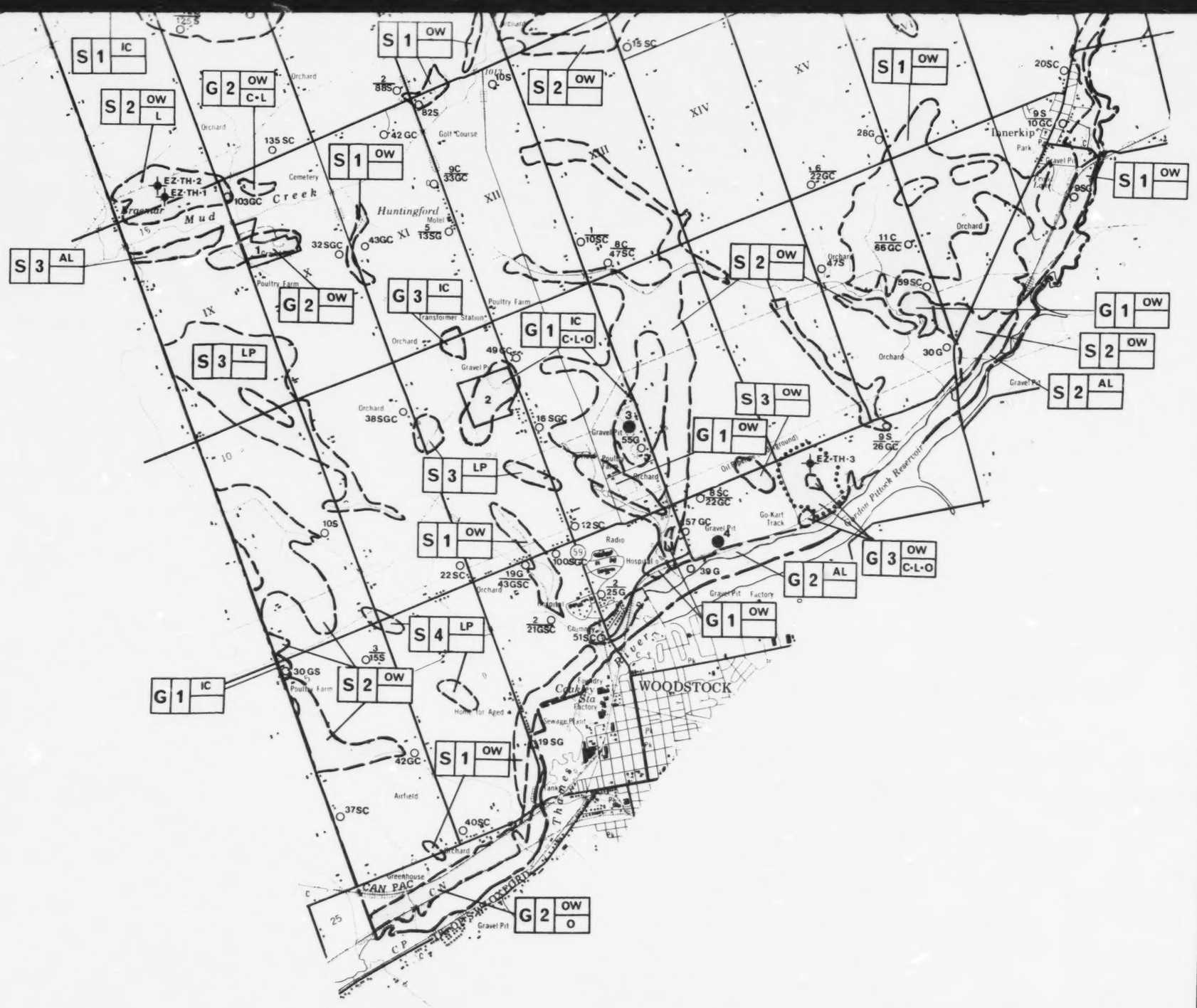

Deposits are identified
quality indicators. Gr
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Gravel Content	

Gravel Content

G	Greater than
S	Less than 35

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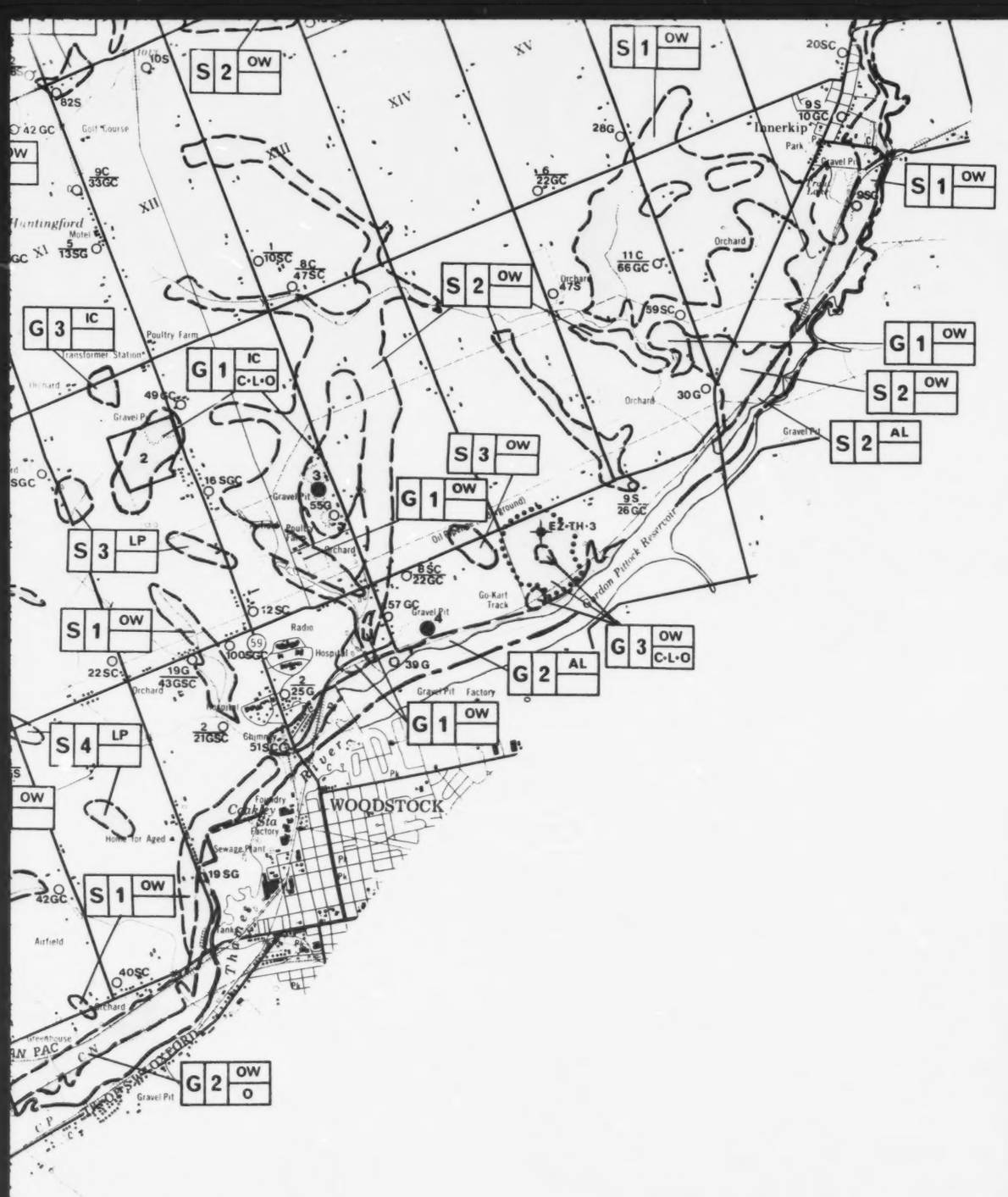

EAST ZORRA TAVISTOCK

DEPOSIT SYMBOL

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Gravel Content	Thickness Class	Geological Type
		Quality Indicators

Gravel Content

G	Greater than 35% gravel.
S	Less than 35% gravel.

Thickness Class

1	1 to 3 feet
2	3 to 10 feet
3	10 to 25 feet
4	25 to 50 feet
5	50 to 100 feet
6	100 to 200 feet
7	200 to 400 feet
8	400 to 800 feet
9	800 to 1600 feet

Geological Type

IC	Undifferentiated Ice-Contact Stratified Drift	OW	Outwash
ICT	Ice-Contact Terrace	LB	Lacustrine Beach
K	Kame	LP	Lacustrine Plain
E	Esker	LD	Lacustrine Delta
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